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Residential plants investment appraisal subsequent to the new supporting photovoltaic economic mechanism in Italy

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ABSTRACT

Solar energy is a fascinating promise for the future of world economies considering both the progressive depletion of natural fossil fuels and the environmental impact of their massive utilisation in energy conversion systems.

After an outlook of more evident techno-economic, environmental and social issues related to photovoltaic (PV) sector, the paper proposes a financial appraisal of a real case concerning a private residential PV building-integrated plant in order to highlight its economic feasibility according to last supporting mechanism introduced by recent Italian legislation.

Contents

1. Introduction

As widely recognised, the raise of anthropogenic greenhouse gas and aerosol emissions into the atmosphere deriving from the use of traditional fossil fuels contributes to destabilise natural cycles. The following global warming is a major and inevitable corollary of a world energy policy based on such resources. Carbon dioxide (CO_2) is the main effluent in this context and all those actions leading to its control have become the leit-motiv of international technical debates on the topic and the concern for many governments [1–3]. At the international scale the problem is exacerbated by the high-rates of economic and demographic expansion of some developing countries [4].

Given these scenarios and the conversion systems supporting such a framework, the future increase in energy needs will be reasonably faced by recurring to a wider use of more polluting traditional fossil fuels. Such an option will determine further environmental imbalances considering the subsequent higher cumulative damaging level rates. Needless to say that Kyoto Protocol commitments will become very hard targets to fulfil for all countries adopting the various market based mechanisms proposed for emission reductions: International Emission Trading, Joint Implementation and Clean Development Mechanisms [5].

More generally in this context, also economic situation would be expected to become more and more complex especially for net-energy importing industrialised countries (like Italy for example) [6]. As a matter of fact, the cumulative effect of increasing energy

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consumption rates summed up to higher international inherent prices could not allow the combination of current standard of living, environmental quality and industrial competitiveness. Specific costs have a significant impact on economic systems mainly through the reduction of profit rates [7]. Not-secondary aspects related to conventional fossil fuels based economies are the social, economic and political concerns/costs due to the instability of Middle East Areas (security of supply and potential conflicts) where the great amount of known fossil reserves are stocked in.

As far as developing countries are concerned, although with different weights and particular references to larger ones, it has to be pointed out that past developing paths – already followed by industrialised nations – are neither resource/energy efficient nor environmental sustainable in the long-term [8]. Nevertheless, these countries have a strategic advantage in adopting new energy options considering their lower "technological inertia" compared to developed ones. As a matter of fact, their involvement in "antiquated" technologies is very limited under the various aspects: infrastructures, capital investments, employments skills, management organisation and political institutions [9]. Furthermore, they could also take advantages from results already developed in industrialised nations, without spending funds on basic research programmes [10].

Despite this recognised strategic role played by energy issues both in developed and developing countries only high oil prices – recent daily quotations have approached also the 150 US$ per barrel psychological threshold – seem to favour energy-saving attitudes as well as substitution processes among energy sources. The promotion of renewable energy sources should become an important goal of national energy policies after both the cyclical crises boosted by the oil-shocks and the environmental imbalances caused by the massive use of fossil fuels [11].

Thus, a triple order of descending consequences could be:

(a) the change in traditional energy policies;
(b) the shift also towards a more different energy framework where renewable technologies have a remarkable strategic role;
(c) a discontinuity in past consuming models and lifestyles [12].

Obviously the needed change for importing energy economies must be contemporarily supported by the public willingness with appropriated fiscal measures to favour a transition period aiming at renewable energy sources adoption.After an outlook concerning main technical, economical, environmental and social issues concerning PV technologies and their adoption, the aim of present paper is to propose an economic analysis of a residential PV grid-connected plants in order to explain the recent Italian legislation adopted mechanism to promote solar PV energy production.

2. Techno-economic, environmental and social main issues concerning PV technologies

Renewable energy technologies have witnessed stimulating improvements both in performance and in reduction of unit costs also as a direct consequence of progressive diffusion within the markets. Solar PV modules and wind turbines are examples of such technological changes [13,14].

Careful attention towards solar energy comes from the fact that the Sun emits energy at a rate of 3.8×10^{23} kW and only a tiny part of this energy (1.8×10^{14} kW) is intercepted by the Earth, which is located at about 150 million km from the Sun. Only about 60% of quantity of energy reaches the Earth surface, the rest is reflected back into space and/or absorbed by the atmosphere and even if just a little part (0.1%) of this energy could be transformed with an efficiency rate of only 10% throughout photovoltaic effect, i.e. the direct conversion of sunlight into electricity with no intervening heat engine it would be four times the world's total generating current capacity [15]. On the counterpart, some inherent limitations linked to intermittency – both at night and under heavy cloud conditions – are negative features that cannot be undervalued in approaching its potential. Hence, the meaningful figure to consider for any area is the "solar ratio" (solar input/local energy use), which varies from less than 100 to well over 10,000 in some developing countries [16].

Moreover, also under a strictly environmental and energetic point of view, PV cells can be considered – both if their total lifetime (from cradle-to-grave) and the whole Energy PayBack Time (EPBT) are taken into account – net CO_2 sinks and net-energy producers as several literature points out [17–20].

As far as PV option is concerned, there are both some remarkable success stories (Austria, Australia, Germany, Japan and Spain) and other less temporarily effective attempts (Finland, Greece and Italy) [21,22]. However, it has to be highlighted, the amount of primary energy produced by PV systems is still very far from having a meaningful effect on current energy balances; PV production is below 1% of total primary energy production [23]. As a matter of fact, current economic costs of kWhs obtained by conventional fossil fuel technologies are still lower than non-renewable ones, but a public long-term energy policy could support non-conventional energy sources technologies in order to overcome unavoidable and expensive further problems exacerbated by increasing oil prices. However, even if the major criticism to PV industry lies in fact that public incentives are crucial elements for its survival, it must be pointed out that also other energy industries receive very massive subsidies by Governments both in a direct manner (i.e. money for appropriate investments) and in an indirect manner (hidden costs related to health impacts, military expenses to sustain favourably political conditions in some regional areas, employment, crop loss and environmental consequences charged on citizens through general tax systems in various ways) [9].

Since now, adopted mechanisms to support the PV sector have been oriented towards two main directions:

(a) feed-in tariffs, considering both the avoided environmental costs associated with poor air quality and reduced greenhouse gas emissions;
(b) capital incentives to acquire PV equipments in order to allow the direct investment cost.

Notwithstanding such mechanisms seem useful for a widespread adoption of these technological options, many homeowners and entrepreneurs consider the high initial capital cost to be the major barrier to adopting PV systems. This psychological aspect is a crucial feature, but it could be overcome – also by more suspicious homebuyers – whether the investment in solar PV technology is considered at the same level and with the assessing techniques of an alternative financial investment form. Obviously, environmental and energetic considerations do not lose their undisputable validity.

International market for solar PV is continuing to expand at a very fast rate: about 35% per year worldwide [15]. This important grow in demand and the subsequent increase in production volume lead to a stable decrease in the price per module [24]. However, even if the increases in the market should follow such rates, they are not sufficient to think to a complete substitution of fossil fuel applications in the short-term. As far as this last aspect is concerned, it is important to highlight today manufacturing solar cells industry is not able to support a too rapid increase in the market demand because a greater amount of investments in

output capability is needed. The economic bottleneck for a rapid change in the present situation lies not in the retail installed price (about \$ 6/W_p in the USA and € 6/W_p in Europe) but in the wholesale part of the chain value given that the cost of the PV module represents 50–60% of the total installed current cost of a system. In such conditions only a wholesale price of about \$1–1.5/W_p after enormous scale up in manufacturing costs and a retail price of about \$2–3/W_p could decisively favour the widespread adoption also by mid-low class residential consumers and the massive diffusion [25].On the strictly technological side, one of the most limiting factors remains the energy efficiency of commercial PV modules. Currently silicon mono-crystalline and poly-crystalline based technologies have efficiency rates in the range of about 13.0–14.0% [26]. However, some new germanium based technologies have proved laboratory tests efficiency rates well beyond such values with an order of magnitude of about 39%. Further meaningful improvements are reasonably expected with appropriate research programmes [15,27,28].

Considering current technological opportunities, the most generally proposed paradigm to support an effective solar energy rapid diffusion is the development of a distributed energy network very similar to the situation already existing in the computer sector with the Internet. This model has its validity especially considering some strategic and critic aspects: less susceptibility to large-scale power outages caused by natural (floods, storms, etc.) or manmade disasters (terrorism, warfare, etc.) than conventional structures [29].

3. The Italian situation

Italian market and application of PV devices is limited if compared with more advanced countries like for example Germany, Japan and USA. As a matter of fact, installed capacity at end-2005 is about 34,000 kW_p; such a level is well under Germany (1,429,000 kW_p), Japan (1,421,908 kW_p) and USA (496,000 kW_p) [15]. However, an important change to improve the status-quo has come from three dedicated decrees by Ministry for Economic Development concerning Feed-in Programme: D.M. 28th July 2005 (labelled as "Primo Conto Energia") with subsequent modification (D.M. 6th February 2006) and, recent, D.M. 19th February 2007 (labelled as "Nuovo Conto Energia"). The market, up to now negatively influenced by bureaucratic delays in all the application procedures, seems to benefit of such progressive simplification steps in order to apply PV systems. Before entering into some details of the new "Conto Energia" with the purpose of explaining the legislation favouring the adoption of PV devices, a brief outlook concerning Italian research and development (R&S) activities and industry current status is due.

As far as research, development and demonstration activities on PV systems and devices are concerned, the main involved subject are ENEA (National Agency for Alternative Energy Sources) and CESI RICERCA. This last subject is a research company recently born from the synergy of ENEA and CESI (the Institute for Research and Certification of Electric Components and Systems) and the support of Universities and CNR (National Council for Scientific Research). ENEA research activity is well concentrated on the set-up and optimisation of fabrication processes of cells, buried contact selective emitter technology. Since 2002, another important research field – where ENEA is involved in – is the PhoCUS (Photovoltaic Concentrators to Utility Scale) Project. Such an effort is mainly devoted to investigate concentrators technologies and to assess the technical and economical feasibility of applications for centralised generation of electricity. CESI RICERCA is mainly carrying out R&D studies in the field of high efficiency solar cells both for terrestrial and space applications. Other important activities by CESI RICERCA are in the fields of components' characterization, performance evaluation of PV systems and in the analysis and testing of PV modules on advanced solar cells (thin films, amorphous silicon, etc.) [30].

As far as industry status is concerned, one important manufacturer is Enipower (formerly Enitecnologie) owned by ENI Italian oil company; its manufacturing facility has an about 10 MW_p/year production capability both on mono-crystalline and poly-crystalline silicon cells. Another important market player is Helios Technology (owned by Kerself Group) also having an about 10 MW_p/year production capability manufacturing facility. Other emerging players are entering into the market from their previous core-business activities considering energy-sector as a strategic one: Marcegaglia Group as an example. Further to large dedicated manufacturing companies, there is also a plethora of Small and Medium Enterprises (SMEs) involved in assembling and encapsulating standard or tailor-made and especially designed modules such as windows integrated cells or using coloured cells [31].

4. Overall economic analysis of a real case

In this section a real rooftop PV system case is proposed and analysed in order to render the more evident as possible the opportunity for citizens to act in a more sustainable and environmentally friend way.

The first aspect to explain for the proposed case is related to the Feed-in tariff introduced by the New Conto Energia [32] that for domestic use (Ministerial Decree dated 19 February 2007) should support new installations adopting the net-metering scheme for small residential applications [33].

Within Table 1 are resumed tariffs paid in nominal terms by GSE (Gestore Servizi Elettrici, a public owned company to manage electrical services) for 20 years to the whole produced electric energy from a PV building-plant complying with specific rules. Such a method is very common in Europe, while is not in the USA [34,35].

The tariff prices decrease to 2% for subsequent years from the year 2008. For example, in case of a "not integrated plant" having a nominal power of 1.5 kW entering into operation in 2008 the tariff is € 0.40 for each produced kWh in the subsequent 20 years; while if it should enter into operation in 2009 the tariff will be reduced by a 2% rate and, hence, it will be equal to € 0.392 for each produced kWh in the subsequent 20 years (i.e. $0.40 - 0.02 \times 0.40$). The same mechanism is applied for further years (as can be seen the tariff is higher for the first operating plants).

Further to this fiscal incentives paid to the total energy production, there is also a net-metering scheme. As a matter of fact, at the end of the bimonthly period, when the energy supplier sends its invoice to the end-user – thanks to specific energy-counter devices – the domestic end-user itself can benefit of the positive (if existing) difference between its own consumption and production. Thus, if its energy-count is negative (consumption > production) the consumer will pay the difference reported in the bill, while if its energy-count is positive (consumption < production) the excess of PV generation will be carried forward to the transaction of the following 2-month period until a maximum 3 years long deadline.

Table 1
Tariffs for PV energy production for different typologies of grid-connected plants.

Nominal power of the plant P (kW)	Not integrated plant (€/kWh)	Partially integrated (€/kWh)	Integrated plant (€/kWh)
$1 \leq P \leq 3$	0.40	0.44	0.49
$3 < P \leq 20$	0.38	0.42	0.46
$P > 20$	0.36	0.40	0.44

Source: [31].

Table 2
Cash-flow analysis/forecasts for the 2.7 kW_p PV residential plant.

Year	A Total cost (€)	B Cash-flow from feed-in incentive (€ 0.49 × production) (€)	C Fixed costs due to yearly maintenance and fixed connection costs (€)	D Savings in electricity costs (2200 kWh × estimated electricity price) (€)	A + B + C + D Total cash-flows (€)
1	−16,730	1455	−130	356	−15,049
2		1442	−135	385	1692
3		1225	−141	416	1704
4		1214	−146	449	1707
5		103	−152	485	1724
6		1192	−158	524	1744
7		1182	−164	566	1768
8		1171	−171	611	1793
9		1160	−178	660	1824
10		1149	−185	712	1857
11	−1300	1139	−192	769	595
12		1129	−200	831	1937
13		1119	−208	897	1983
14		1109	−216	969	2034
15		1099	−225	1047	2092
16		1089	−234	1131	2155
17		1079	−243	1221	2226
18		1069	−253	1319	2303
19		1060	−263	1424	2385
20		1050	−274	1538	2478

Source: personal elaboration of proposed data.

In this manner, the consumer could verify its position with credits or dues in each subsequent 2 months' payment.

Hence, the complete mechanism gives benefits for citizens under two different aspects:

(a) incentives paid by GSE for energy produced from PV panels;
(b) savings in domestic energy consumption.

Proposed data in the following example are both derived from real case and estimated on the basis of reasonable technical features furnished by a solar modules installer company not mentioned for confidentiality reasons. Needless to say that, the here assumed cost of the rooftop system is the overall amount needed in order to install the complete PV plant: solar modules, electric devices, project, bureaucratic license and necessary building adaptations, labour and materials all VAT included.

Assumptions relating to calculations are the following:

- Geographical site = Cesena, Emilia-Romagna Region (Italy), geographical coordinates of the site: latitude: 44°08′ N; longitude 12°13′ E; 44 m over the sea level;
- Electrical energy yearly consumption = 2200 kWh. Such a value is assumed as a constant for precautionary reasons; if it were superior, the possible marginal savings would be higher and estimates would be undervalued rendering more profitable the whole project;
- Nominal power of the solar plant = 2.70 kW_p;
- Yearly average estimated production of the plant = 1100 kWh per kW_p of nominal power of the solar modules. Such a value is a precautionary one and it takes into account possible and unknown reductions from optimal theoretical figures resulting as an example from the not perfect orientation and other unforeseeable factors [36];
- Average estimated loss of yearly efficiency in energy production for various reasons = 0.90%;
- Installation overall final end-user cost of a totally integrated-roof plant consisting in 15 solar modules, produced by a primary Japanese manufacturer: € 16,730.00 (VAT at a 10% rate included);
- Increasing yearly rate of electrical energy prices based on available domestic price data from electric bills 1999–2007: 8%;
- Starting retail electrical average energy price: € 0.162/kWh – VAT included – in 2008;
- Fixed costs related to yearly connection to the grid and maintenance are increased following a 4% rate.

In Table 2 all data needed for the investment appraisal during a 20-year period are reported given that feed-in incentives for grid-connected plants are of the same time period, even if warranty on 80% of modules' efficiency is for 25 years. At the year 11th the cash-flows consider also an outflow due to an inverter device substitution estimated at the current (2008 year) cost with inflation after 10 years.

All figures in the last column are rounded for simplicity reasons. Needless to say that:

(a) if the life of the plant would be longer the calculated data should be more favourable to the investor;
(b) if there were unpredictable events (like for examples ruptures, interruptions, or weather accidents) the calculations would be not correct and the calculated data should be less favourable to the investor;
(c) incentives for private/domestic consumers are not taxable given that incentives are not considered revenues for Italian tax legislation in this case.

From an economic viewpoint, hence, the purchase of a PV system means an initial high expenditure of capital resources with the expectation of benefits under the form of the valorisation of solar electricity obtained both in monetary incentives and consumption savings. The cash-flows forecast is a crucial element in this assessment process. In the proposed example all these aspects are taken into account in order to render as consistent as possible the case.

To evaluate the profitability and the economic aspects of the project the classical and widely recognised methods here adopted are: the net present value (NPV), the payback time (PBT) and the internal rate of return (IRR) [37,38]. Without entering into

excessive technicalities, neither having any pretension to be exhaustive on the theoretical (and more sophisticated) related aspects, a brief description of each investment appraisal method is proposed for the specific calculations.

The proposed numerical example is related to the solution of energy needs of a typical Italian family (three/four members) with the 2008 fiscal year net-metering scheme. This specification is important because as of 2009 fiscal year the calculation method will be subject to some modifications rendering impossible to elaborate an exact calculation procedure by using the new parameters. However, specific answers by GSE managers concerning these changes have pointed out only marginal economic variations (about 2–3% reductions) as far as savings in personal consumption are concerned (column labelled as D within Table 2), because a lower tariff should be paid to the energy injected to the grid. Such tariff will be a function both of geographical zones and of the injection hours. Unfortunately, these unknown and unpredictable factors do not allow to make a rigorous investment appraisal for years to come by using the 2009 mechanism as the 2008 scheme allows. Without change will be the incentives on produced energy as reported in Table 1. For these reasons, elaborated calculations are presented in their original 2008 form assuming this year as the paradigm to assess such kind investments and evaluating in a negligible manner the effects due to changes in the column D of Table 2 on the overall assessment of PV investment determined by those factors.

4.1. Net present value

This is the most accepted standard theoretical method for financial appraisal of long-term projects. It is defined as the sum of present values of all cash-flows (inflows and outflows) related to the investment. The classical model is

$$\mathrm{NPV} = -I_0 + \sum \frac{(CF_n)}{(1+r)^n}$$

where I_0 = the capital initial cost to pay (cash-outflow); CF_n = the yearly net cash-inflows; n = the number of years involved in the evaluation time of the investment (duration); r = interest (discount) rate, hurdle rate or opportunity cost of capital.

Following such a method the investor should accept the investment if the calculated NPV is >0; i.e. if at the end of the investment period he will have more money value than at the beginning. In general, the higher the NPV the greater the financial benefits will be.

For what concerns the NPV method, further to consistent evaluation of cash-flows, main uncertainties are for the interest rate determination that is the most controversial/critical aspect involved in its adoption and calculation. As a matter of fact, it could seriously affect the profitability of the decision. The interest rate should be defined as an expression of the risk of the investment itself; the more the risk, the higher the interest rate. Often, its determination is linked to the experience and sensibility of the investor with reference to the risk perception within the market; however, theoretical principles are defined in order to support a reasonable choice flanked to practice experience.With specific regard to the proposed case, it has to be pointed out that as can be seen from Table 2, the I_0 value and the CFs for the various years are determined by considering both installation costs as above specified and the estimates considering reasonably revenues deriving from the feed-in tariffs due to the incentives plus savings in electricity consumptions. As far as the interest discount rate is concerned, its choice follows theoretical statements and corporate practice and is assumed as the sum of the yield deriving from a financial asset having the same duration and probability of default at the date of the calculation plus a risk premium. In our example a 20-year Italian Treasury Bond – labelled as BTP in financial markets with maturity in the 2029 and an interest-coupon yield equal to 5.25% [39] – is chosen to appreciate the first aspect, because both feed-in incentives and coupon interests are similar Government's promises and, thus, they are assumed with the same risk rate. The additional risk premium could be proposed in different estimates for a twofold sensitivity analysis; 10% of the assumed free-risk rate, thus the overall interest rate will be $5.25\% + 0.1 \times 5.25\% = 5.8\%$; or also 50% of the assumed free-risk rate and the consequent overall interest rate will be equal to 9%. Needless to say that this part of the assessment procedure can be – as previously outlined – subject of several criticism but it is impossible to eliminate such subjective issues. Considering these assumptions the final NPV results are € 5383 in the first hypothesis (r = 5.8%) and € 995 in the second one (r = 9%). As can be noted, results are very influenced by the choice of the interest rates; a greater rate decreases NPV and vice versa.Given that the NPVs are >0 the investment should be accepted/made.

4.2. Payback time

This method determines the profitability of the investment by the calculation of the required number of years needed to gain the initial investment from the cumulative cash-flows of the project. This method is easily understandable and well accepted by SMEs, even if the main drawbacks lie in the fact that it ignores the produced cash-flows after the cut-off date. Hence, it may hide good financial opportunities if not carefully considered. An alternative version of the method includes also the financial aspect by taking into account the required number of years for the present worth of the inflows to equal the present worth of the outflows (more properly named Discounted Payback Time—DPBT). In general, considering both the versions of the method, the investment is very attractive if the number of years needed to recover the initial capital cost is low, i.e. less time is needed to recover initial investment. In the present case, the calculation of the PBT – assumed in its classical form and not following its DPBT version – is between 9 and 10 years, as can be easily appreciated by Table 2 data summing the values of the last column (total cash-flows).

4.3. The internal rate of return

The internal rate of return is defined as the rate of discount making NPV = 0. This is to say:

$$\mathrm{NPV} = -I_0 + \sum \frac{\mathrm{CF}_n}{(1+r)^n} = 0;$$

thus, the unknown to calculate is: r (labelled as IRR).

This method simplifies the reasoning and its interpretation because after the estimation of CFs there is no need to evaluate an appropriate interest discount rate. Consequently, there are less subjective considerations in the assessing procedure. Under an economic point of view, the IRR defines the cost of financial debt needed in order to sustain the whole operation. In this sense, such an index is very important for the investor given that it provides a meaningful measure of the return of the investment. The investor should decide to accept the investment if the specific IRR is considered sufficiently high. Put in another way, if the opportunity cost of capital is less than the IRR. As far as the presented case is concerned, the calculated IRR is 10%.

5. Conclusions

Adoption of solar PV technologies could be an important help in the issues of energetic needs, environmental quality and keeping current standard of living in the medium term [40]. Hence, specific supporting policy measures should be adopted by those countries

like for example Italy that, given their situation of net-energy importers, have the opportunity to invest in such a promising industry with all related economic and social benefits. Moreover, it must be pointed out the PV manufacturing industry is a labour-intensive sector and it should produce higher levels of employment than equivalent levels of investments in conventional energy industry with a factor of about 2.3 [9].

Further to public authorities, also citizen are "forced" to be involved now in a more pro-active way to give their contribution. However, many positive results depends also on information available by public opinion in order to re-orient industry and to influence governments and public administrators alike. Information on the topic is a very crucial elements in this field given that social acceptance of renewable energy sources is quite mature [41].

Economical constraints are less stringent than in the past due to fiscal incentives as the proposed profitability indexes have showed in the above-mentioned case. As a matter of fact, in a range of € 5000–7000 per installed kW_p also a private middle-class consumer can afford the initial high capital cost considering the acceptable payback period (about 10 years) of the investment. However, further technological improvements and economic savings are expected and needed in order both to render accessible the PV opportunity also to a wider group of middle-low class consumers in the industrialised countries and to most developing countries as well. Only in such conditions the PV-distributed option will have its decisive affirmation.

Moreover, the widespread adoption of this technology – although many developments are needed with particular regard to efficiency [42] – seems favourable considering that also several aesthetic issues in building integrations are solved with appropriate and specific solutions [43]. As far as Italy is concerned, a PV massive involvement could be – in theory – not impossible considering that to produce all electricity currently consumed the needed PV modules should employ less than 1% of the total area of the country [23]. Obviously, at the international level, if techno-economic improvements should improve global efficiency, the PV option could be seriously thought as an alternative, economically viable, technologically feasible opportunity to substitute the more as possible traditional fossil fuels.

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